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TITLE:	LASER ABLATION OF WAVEGUIDE STRUCTURES	

Clean Version of Amended Specification

Page 5, Paragraph 1

B1

For given exposures utilized in experiments, the substrate temperature was thought to be approximately the same as that induced at the surface. The laser was operated initially with unfocussed 10W of CW power ($\sim$140 W/cm^2). When the laser was later focused, temperatures readily exceeding the melting point of silica were achieved resulting in laser vaporisation and ablation.

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In the experiments to determine the parameters of operation, optical spectra were taken, of the MZ device using a broadband erbium-doped fibre amplifier (EDFA) and a spectrum analyser with a resolution of 0.05nm, limiting the birefringence splitting which can be measured to $\sim 1\times10^{-5}$.

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In initial experiments, the longer arm of a MZ device (12 μm SiO_2 cladding and buffer layers, 4×5 μm GeO_2- doped core, Δn $\sim$0.01) was processed for testing and confirmation of the concept. Measurements were taken at intervals after briefly halting the exposure at fixed times since the fibre coupling was increasingly affected by longer exposures. It was noted that both TE and TM shifted to longer wavelengths indicating an increase in refractive index. The TE effective index eventually increased more rapidly such that the splitting was

reduced as shown in Fig. 4 which shows the change in wavelength splitting between TE and TM eigenstate with exposure to unfocussed light. Initially, however, as shown in Fig. 3, an increase in the splitting observed. We believe is related to an initial increase in compressive stress and subsequent compaction of the core glass. The magnitude of reduction is sufficient to allow compensation of birefringence in most planar silica-on-silicon devices where the splitting is much lower than the device chosen here. Further, this value is unsaturated.

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The power density of the CO_2 laser was then increased to ~ 1.3 kW/cm^2 by focussing to a 100 μm spot size such that we exceed the threshold necessary for vaporisation for an exposure of less then 0.2 s. Ablation was confirmed under an optical microscope after gently cleaving through one damage region of the surface. By controlling the duration of the exposure it was possible to control the depth to which material is removed. The spectral responses when exposing the longer arm were found to shift to shorter wavelengths indicating a decrease in refractive index. However, the TM state was found to decrease more rapidly resulting in a large drop in the birefringence splitting. The decrease in refractive index and the localised ablation indicates that in this case dilation and stress compensation or relaxation at the core are the main factors responsible for the reduction in birefringence. Fibre coupling is significantly more stable (an important advantage for *in-situ* monitoring) and the process is clearly more efficient than thermal annealing of the material. This will affect the effective propagation constants for each polarisation state as well as introduce some polarisation dependent loss. The result is that this can be used to achieve balancing of the optical energy for each eigenstate and hence result in a matched and improved spectral response of the device. Fig. 4 shows the change in effective index as a function of shots fired in the same region and shows the convergence of birefringence when exposing the longer arm. It was noted that subsequent successive shots on the same region did not contribute any further. Indeed a small reversal was observed. Exposing the shorter arm

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showed spectral divergence, as expected if polarisation compensation has been achieved.

B 4

Page 7 First full paragraph

The spectral response for a second device utilized in experiments (essentially a polarisation splitter) prior to irradiation is shown in Fig. 5. The poor fringe contrast and the difference between TE and TM responses indicates that the input coupler is polarisation sensitive and that different amounts of light are split for each eigenstate. As a result, the intensity of light in each arm is not equal leading to poor fringe contrast upon recombination at the output coupler, particularly in this case of the TE state. The polarisation sensitivity between couplers is very difficult to eliminate completely in silica-on-silicon systems where strain is not readily removed. Fig. 6 illustrates the end results on the device once the process of irradiation ablation was optimised. An improvement is fringe contrast to 20 dB for both TE and TM states was achieved after five shots along the longer arm (power density ~ 1 kW/cm^2). The total increase in loss necessary to balance the polarisation states in this particular device was ~ 0.12 dB for TM and ~ 1.2 dB for TE.

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Page 8, First Paragraph

Secondly, the ablation of the waveguide can also be extended, as shown in Fig. 8, to the area surrounding the core 25. This can be utilized to effect the operation of the core and the overall device. For example, in Fig. 9, there is illustrated the utilization of ablation to form a refined surface 30 which can be utilized to provide for more accurate sensing by the core 31. Further, the ablation of the surface can be utilized in the construction of complex semi-conductor devices having predetermined operational characteristics. For example, in Fig. 10, there is illustrated the example of deposition of a subsequent layer 33 which can comprise zinc oxide, $BaTiO_3$ or the like so as to provide for a functional semiconductor device.

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